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Editorial: Multi-scale ecological indicators for supporting sustainable watershed management

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ABSTRACT

Water supply is a significant issue for realizing sustainable water resources development at the watershed scale. Such an issue is mixed with many human and ecosystems related factors that need to be characterized, evaluated, and simulated for achieving sustainable watershed management. Thus, cascades of ecological indicators need to be used for describing and quantifying dynamics of such factors and the associated processes and conditions. They could facilitate assessment, simulation, and management of many ecological indicators at the context of watershed. A number of relevant studies were collected and compiled in this special issue. Its purpose is to report a number of the latest research related to multi-scale ecological indicators for supporting sustainable watershed management. The contributions incorporated diversified and creative applications of theories and methodologies in multiple fields, including ecology, modelling and management. All selected papers underwent a thorough peer review process, with at least two rounds of reviews. Following the journal guidelines and requirements, all submitted papers were reviewed by at least two experts. These papers contributed in different aspects to the topic of "multi-scale ecological indicators for supporting sustainable watershed management", providing a deep understand of relevant issues and presenting novel approaches, techniques and applications for dealing with such issues. The papers can be categorized into three groups, covering studies upon multi-level indicators of inherent mechanism, internal function, management modeling, and ecosystem analysis.

1. Introduction

Unreliable water supply due to insufficient water quantity and poor water quality is a major obstacle for realizing sustainable water resources development at the watershed scale. This is leading to a variety of adverse impacts not only on human society, but also on indigenous ecosystems. Nevertheless, exploitation of new water sources and construction of extra water supply equipment and devices are increasingly challenging due to the objection of local communities, and the scarcity of available water resources. Thus, efficient, equitable and sustainable water management as well as effective policy instructions from decision-makers are significantly desired for multi-level jurisdictions within a watershed. Moreover, climate change and human disturbances could affect many water resources management factors and processes, and lead to significant spatial and temporal variations in water resources and the associated environmental and ecological conditions. Such conditions need to be characterized, evaluated, and simulated for achieving sustainable watershed management. Then, cascades of ecological indicators need to be used for describing and quantifying dynamics of these conditions. However, such indicators are highly complicated, involving a large number of social, economic, ecological environmental, technical, and management factors, which are further multiplied by complex spatial variabilities and cascading effects. At the same time, a watershed comprises plenty of interactive parts, such as rivers, streams, lakes, wetlands, reservoirs, dams and bifurcations, as well as cities, towns, and water users. These complexities can be robustly addressed through incorporation of multi-scale ecological indicators as well as the associated theories and techniques within the existing watershed management methodologies.

Previously, there were many studies on watershed management. However, most of them could neither explore the inherent characteristics of a watershed nor comprehensively consider effects of multi-scale ecological indicators, as well as their interactions and the associated uncertainties. Limited research was undertaken on methodologies and applications that could handle characterization, simulation, assessment, optimization and uncertainty analysis of ecological indicators under multiple scales within a watershed. These lead to difficulties in acquiring sound bases for supporting the formulation of desired policies and strategies of sustainable watershed management.

Comparatively, a number of studies has been conducted more recently related to "multi-scale ecological indicators for supporting sustainable watershed management". These studies provided opportunities for exchanging ideas and experiences in studying multi-scale ecological indicators to support sustainable watershed management under disturbances of climate change and human activities. They are covering assessment, simulation, and management of many ecological indicators at the context of watershed. A number of such studies were collected and compiled. The purpose of this special issue is to report a number of the latest research related to multi-scale ecological indicators for supporting sustainable watershed management. The contributions

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incorporated diversified and creative applications of theories and methodologies in multiple fields, including ecology, modelling and management.

2. Special Issue Papers

After the initial invitation, all selected 49 papers underwent a thorough peer review process, with at least two rounds of reviews. Following the journal guidelines and requirements, all submitted papers were reviewed by at least two experts. These papers contributed in different aspects to the topic of "multi-scale ecological indicators for supporting sustainable watershed management", providing a deep understand of relevant issues and presenting novel approaches, techniques and applications for dealing with such issues. The papers can be categorized into three groups, covering studies upon multi-level indicators of inherent mechanism, internal function, management modeling, and ecosystem analysis.

2.1. Indicators for supporting mechanism investigation and analysis

Through conducting multiple experimental studies, Yang et al. (2018a) analyzed and simulated processes and the associated effects of physical clogging on performances of a vertical subsurface flow constructed wetland (VSFCW) system. In their research, the accumulation of inorganic solids and the corresponding changes in performance indicators were analyzed over time in the top layer of VSFCW with a constant contaminant loading rate. The results indicated that concentration of the total suspended solids (TSS) in outflow had a significant correlation with that of the inflow. Also, TSS reduction rate remained steady during the experimental period (46.4 ± 8%), resulting in a linear relationship between the accumulated solids and the effective porosity over continual operational time (R^2 was 0.871 and 0.797, respectively). The infiltration rate declined rapidly during the first 60 days of operation, followed by a fluctuation period of approximately 80 days, with a descending tendency slowing down in infiltration rate. A significant correlation was observed between the accumulated solids and the porosity ($P < 0.01$, and Pearson correlation coefficient = -0.776). The porosity was also correlated with the infiltration rate ($P < 0.05$), but no direct correlations were observed between the levels of accumulated solids and the infiltration rates ($P = 0.11$). Formulas were effectively employed to quantify the relationships among these indicators, with a good fit between the simulated and the measured values.

Zheng et al. (2018) conducted studies in the hinterland of Qinghai-Tibet Plateau (QTP), and Three-River Headwaters region (THR) that feature unique eco-environmental conditions, fragile and vulnerable ecosystems under climate change. To investigate the impacts of varying climatic conditions, normalized difference vegetation index (NDVI) was employed as an indicator to reflect responses of vegetation dynamics. A series of pixel-based vegetation dynamics stepwise-cluster prediction (VEDSP) models were proposed to establish the relations between NDVI and climatic conditions through using remotely sensed precipitation and temperature. The obtained simulation results for training and testing showed good agreements with the monthly NDVI observations. Rather than air temperature, the precipitation was identified as the critical climatic indicator to multiple NDVI values, especially the 2-month consecutive average precipitation. The developed VEDSP models were further applied to predict temporal and spatial distributions of NDVI values for five years (i.e., 2020, 2040, 2060, 2080 and 2100) according to climatic projections of Euro-Mediterranean center on climate change climate model (CMCC-CM) under scenario of RCP4.5. The projected changes of NDVI indicated a slightly significant positive tendency in annual average NDVI values, while the monthly peak values of NDVI for the entire THR would decrease by 5.34% in the future relative to the historical averages of the time period from 2000 to 2013. Distinct effects of precipitation and temperature on the responses of NDVI were further demonstrated. Findings from this study could be used to help analyze ecological effects of climate change and enhance the understanding of ecological changes in the future.

Barbosa et al. (2018) predicted future risks of Limnoperna fortunei invasions in Brazil through the employment of cellular automata. In South America, the presence of the non-native mollusc Limnoperna fortunei (Dunker, 1857; Mollusca, Bivalvia, and Mytilidae) in rivers and reservoirs may result in several impacts on the environment and economic activities. At the continental scale, the factors that mostly influenced the dispersion of the species were anthropogenic vectors such as the movements of boats. Due to this, distribution models based solely on climatic variables frequently failed to predict the areas that were subject to invasion, both spatially and temporally. An alternative to overcome this problem would be the evaluation assuming the phenomenon as a complex system. In their research, a cellular automata model was employed to predict the spread of golden mussel in the Brazilian territory, at a temporal and spatial scale. Three parameters of interest were assumed, including altitude, characteristics of the river, and human population density. Transition rules were defined based on multiple considerations discussed in the article. The algorithm estimated satisfactorily the risk of invasion by L. fortunei to 2016, and the simulations for the years 2030 and 2050 predicted a high risk of invasion in north and northeastern Brazil. The increased risk of invasion predicted by the model for the next decades indicated that prevention and control measures should be applied immediately. This is of the utmost importance for the country to be able to comply with the #9 Aichi target.

In the study by Yi et al. (2018), the root of riparian Homonoia (*RRH*; Homonoia riparia Lour), a medical plant with a high economic value, is mainly distributed at riparian areas in Southeast Asia. Its population has declined significantly. The species has become endangered in recent decades. Understanding the habitat requirements, evaluating the habitat quality, and predicting its potential habitat are significant for protecting the species. In their research, 211 occurrence records of the RRH were collected globally. The key eco-factors influencing species distribution were selected based on correlation analysis and principal component analysis. Habitat suitability simulation were found on four climate-warming scenarios (i.e., RCP 2.6, RCP4.5, RCP6.0 and RCP8.5) given by IPCC. It was resulted that both the suitable areas and the suitability of the RRH habitats increased along with climate warming. The increasing range would achieve the maximum under scenario of RCP4.5.

Previously, studies on benthic algae and hydrodynamic characteristics are rarely conducted in natural streams. In the research by Wang et al. (2018a), a natural stream was selected as a test field. Benthic diatoms were sampled and collected on site. Stream physicochemical characteristics was then measured in the laboratory. Hydrodynamic characteristics was estimated through the adoption of a numerical simulation model. On these bases, the corresponding relations between benthic diatom biomass, stream velocity and shear stress at different sections were analyzed over one dimension. The corresponding relations between benthic diatom biomass and stream velocity and depth were then investigated over 2 dimensions. The results showed that the suitable flow range for benthic diatoms was approximately 0.85 to 1 m/s and the suitable shear stress was approximately 24 to 28 N/m^2 of the one-dimension case. Of the two-dimension case, the suitable velocity and stream depth were 0.9 to 1.1 m/s and 0.40 to 0.48 m, respectively. Therefore, both along the stream and in cross-section, there would always be a range with suitable hydrodynamic characteristics to support a relatively high biomass of benthic diatoms. Outside of this range, however, the biomass would decrease regardless of whether the values of the hydrodynamic characteristics be higher or lower. The study conclusion could provide a reference for supporting stream ecological assessment and restoration.

To improve water quality and alleviate eutrophication in a polluted urban lake, water diversion, a common method of basin management,